



Determining the Cause of Elevated Lead Levels in DC

Treatment is underway to reduce lead levels in the District's drinking water. Why did lead levels increase in the first place? How did experts identify the most appropriate treatment?

This *Research Newsletter* presents the results of research funded by the DC Water and Sewer Authority (DCWASA), the Washington Aqueduct, and the U.S. Environmental Protection Agency (EPA). The science of drinking water in general, and the elevated lead levels in particular, are complex. The purpose of this *Newsletter* is to provide a general overview of various research studies for the interested reader. See the "More Information" section at the end of this *Newsletter* for detailed reports of many of the studies described here.

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The Culprit: Lead Service Lines

In order to control lead in drinking water, DCWASA needed to identify the source of the lead. Because laboratory tests showed that water leaving the treatment plants and in the mains contained almost no lead, DCWASA zeroed in on service lines and home plumbing.

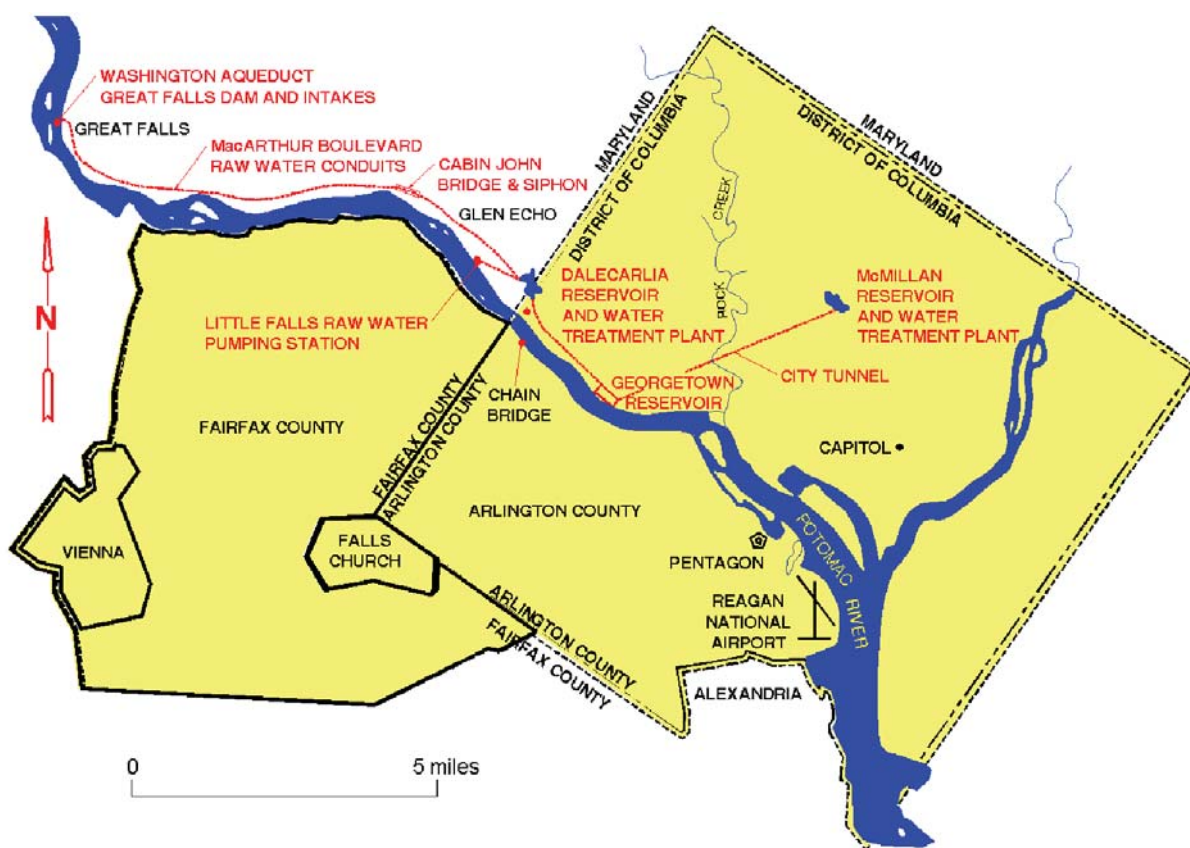
DCWASA worked with corrosion experts to develop a lead profiling procedure at customers' homes to track the release of lead. Lead profiling requires that residents let the water sit in their plumbing system for at least six hours. (This usually occurs while

Lead can leach from

- ▶ lead solder used to weld pipes together;
- ▶ faucets and fixtures;
- ▶ bronze water meters; and
- ▶ **service lines** that connect your house to the water main under the street.

people are at work.) At the end of this holding time, DCWASA personnel collect 15 to 20 1-liter samples of water from the kitchen tap and analyze each for lead.

Where Does DC's Drinking Water Come From?



DC drinking water comes from the **Potomac River** and is treated by the **Washington Aqueduct**. The Aqueduct sells water to **DCWASA**, as well as Arlington and Fairfax Counties in Virginia (The Aqueduct's service area is shown in yellow). DCWASA distributes the water to **DC residents**. **EPA** regulates the quality of the drinking water.

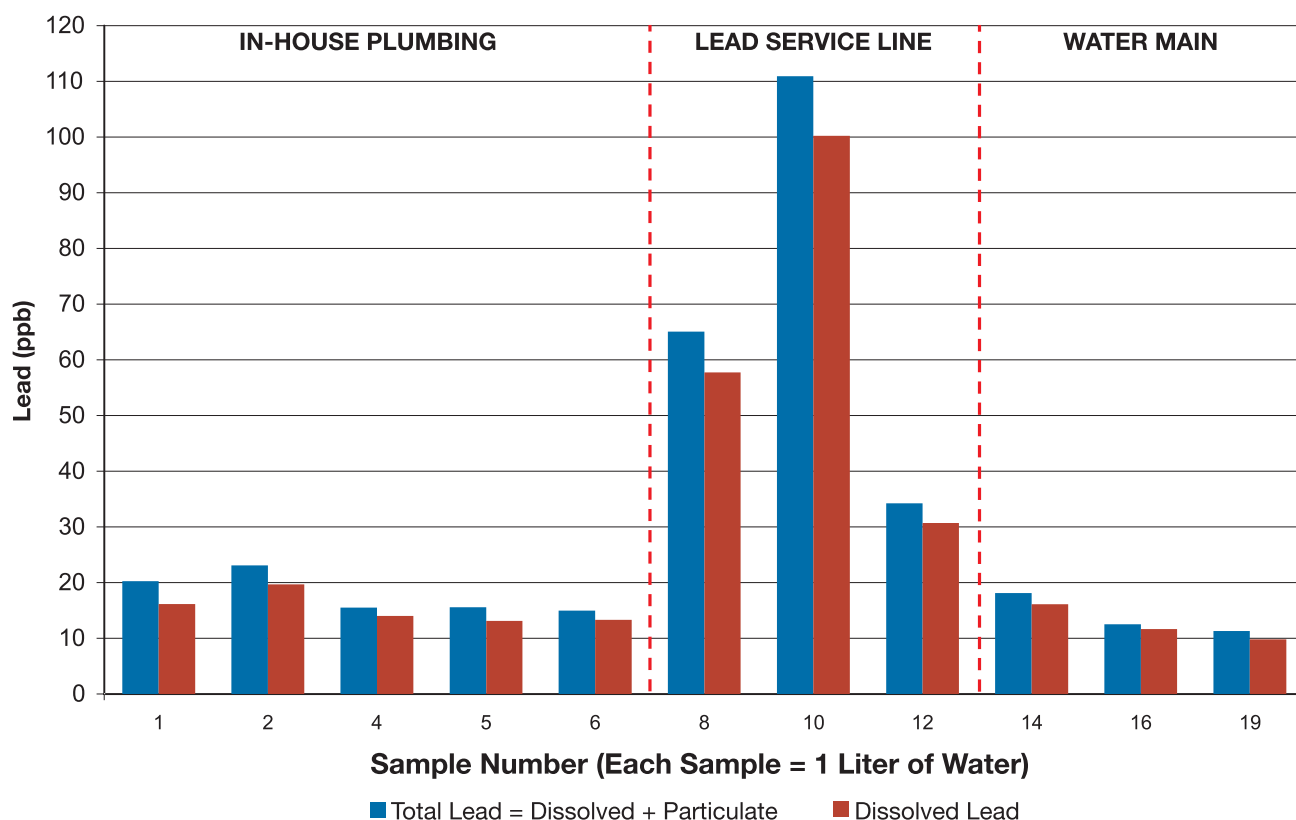
Based on the length and diameter of the household plumbing, DCWASA can approximate where each liter of water was stagnating during the holding time. For example, the first liter of water drawn would have been sitting in the faucet and home plumbing system. A few samples later would represent water from the service line between the house and the water main. The last few samples would be from the water main under the street. Most of these profiles were done at homes with lead service lines.

Figure 1 shows typical lead profiling results for a home with a lead service line. Water from the inside plumbing and the water main had low lead levels. **Lead levels were highest in the water from the lead service lines.** Lead concentrations in water from the service lines typically ranged from 70 parts per billion (ppb) to 150 ppb (EPA's lead action level is 15 ppb). Profiles from

homes *without* lead service lines always had low lead concentrations.

Another important finding of DCWASA's lead profiling work was that most of the lead is **dissolved**, as opposed to particulate, lead. DCWASA filters each water sample to separate the dissolved and particulate lead so that they can be measured separately. While the form of the lead is not important in terms of health effects, it can provide clues as to how lead gets into drinking water. Particulate lead indicates that the corrosion scale is detaching from the pipe wall by a physical process. Dissolved lead, which is the predominant form found in the District's water, indicates that the lead is being dissolved through a chemical or biochemical reaction.

Figure 1 Lead Profiling Results from a House with a Lead Service Line
(Samples collected in early 2004)



Source: DCWASA

Lead Scale Analysis Provides Key Information

DCWASA's lead profiling work indicates that most of the lead in DC's drinking water is leaching from lead service lines. What is causing this to happen? And why now?

To answer these questions, scientists from EPA's Office of Research and Development used a procedure called **X-ray diffraction**. EPA obtained sections of lead service lines that had been extracted from the DC water system. The insides of the lines were carefully scraped to remove the "scale" of lead deposits that had formed over time. The removed scale material was ground into a powder and spread onto a quartz plate. A sophisticated machine bombarded each plate with X-rays, then measured how the rays diffracted (or changed direction) when they hit the sample. Diffraction patterns are unique for different chemicals. The diffraction patterns for the DC samples told researchers the exact chemical makeup of the lead scale. EPA repeated this test with several lead service lines and verified the findings using other methods.

The X-ray diffraction analysis showed that the lead scale in DCWASA's system was made up mostly of lead oxide (PbO_2) compounds (Pb is the chemical symbol for lead, O is the symbol for oxygen). Although lead oxide scales have been identified in a few other water systems, the majority of the lead scales EPA has analyzed are made up primarily of lead carbonate and lead hydroxy carbonate compounds.



Inside of lead service line extracted from DC water system

The Working Theory

Before 2000, chlorine was oxidizing the lead and keeping it on the pipes. When chlorine was replaced with chloramines in late 2000, the lead was no longer being oxidized and began dissolving very slowly into the water.

Why is DC different? The working theory put forward by EPA researchers is that the lead oxide scale formed in the past when the water was treated with chlorine. Prior to 2000, DCWASA maintained a high level of chlorine in the drinking water distribution system to control coliform bacteria. During this time, chlorine oxidized the lead to form a PbO_2 scale. PbO_2 is generally "insoluble," meaning that it does not dissolve into the water. When DCWASA switched from a strong oxidant (chlorine) to a weaker oxidant (chloramines) in late 2000, the lead was no longer being oxidized and began slowly dissolving into the water.

Field and laboratory studies confirm EPA's finding. Most of the lead in DC's drinking water is dissolved (not particulate) lead, indicating that a chemical reaction similar to the one described here is taking

place. In the spring of 2004, the disinfectant was changed back from chloramines to chlorine for one month to clean out the pipes. Near the end of this period, DCWASA noticed a dramatic reduction in lead levels.

So why have the Aqueduct and DCWASA not switched back to free chlorine permanently to reduce lead leaching? The treatment was originally changed from chlorine to chloramines to reduce the levels of **disinfection by-products** (DBPs) in drinking water. Some of these DBPs have been shown to cause cancer and reproductive effects in laboratory animals. Changing back to chlorine could increase risks for all customers and would likely cause DCWASA to exceed federal standards for DBPs.

This interplay of disinfection methods and lead levels illustrates the challenges that water systems face in attaining simultaneous compliance with various drinking water regulations.

Raising the pH is *Not* a Lead Control Option

Raising the pH is a common way to control lead levels in drinking water. pH is an indication of the acidity of water, with a pH of 7 considered neutral. High pH levels (more basic water) can result in the formation of *less* soluble lead compounds, meaning that they will not dissolve into the drinking water.

Historically, the Washington Aqueduct has added small amounts of lime (calcium oxide) to the water to maintain a high pH and control for lead. Minimum pH goals of 7.4 to 7.8 were set by EPA in 2002, although typical pH values of DC water were often higher. When the lead levels increased in 2003, some technical experts recommended adding more lime to raise the pH even more (consistently above 8.8) to help curb the lead leaching.

To study different lead control strategies, the Washington Aqueduct and its expert consultants used a computer model to predict how effective each strategy would be. This “desktop” study was also used to predict unintended consequences—

things that the water system does not want to happen as a result of a new treatment.

When lime (calcium oxide) is added to water to raise the pH, there is a concern that too much calcium carbonate will precipitate out in solid form into the drinking water. Calcium carbonate is the whitish-gray substance that can clog shower heads or leave a film on shower doors. It can clog pipes, foul water heaters, and cause the water to have a white, cloudy appearance.

The Aqueduct’s computer model showed that adding lime would cause too much calcium carbonate to precipitate out into DC’s drinking water. Thus, the Aqueduct and its treatment experts concluded that raising the pH of the water was *not* a viable solution to the lead problem. They recommended that, instead, orthophosphate treatment be used to reduce lead in drinking water. Orthophosphate is a tasteless, odorless, food-grade chemical that works by reacting with lead to form a thin coating on the inside of lead pipe and plumbing fixtures.

Orthophosphate Reduces Lead Leaching in the Lab

To complement the Washington Aqueduct’s desktop lead control study, DCWASA conducted a series of loop experiments in the laboratory to test the effectiveness of various lead corrosion control strategies. These loop experiments involve circulating tap water through extracted lead service lines,

then measuring how much lead from the service line leaches into the water.

One strategy tested in several loops was orthophosphate treatment. Figure 2 presents results from “Stagnation Loop 3,” which are typical of the

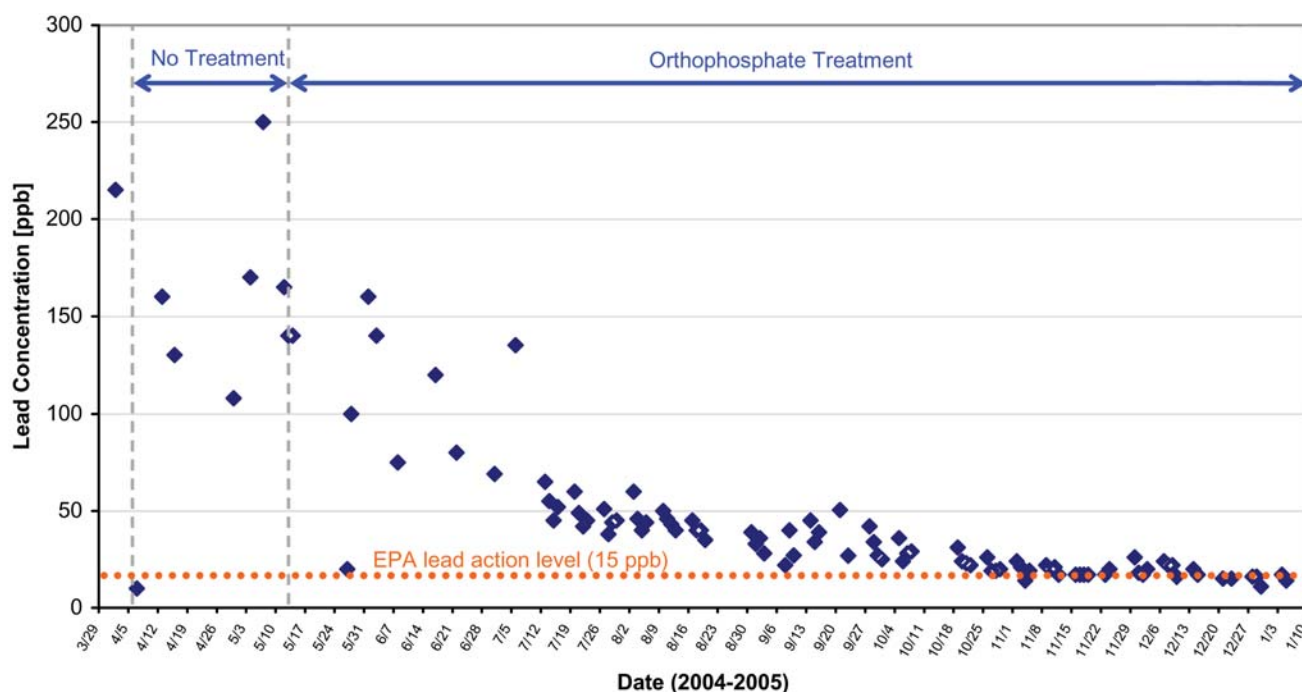
orthophosphate treatment experiments. Each data point on the graph represents the accumulated lead concentration in water that has circulated through lead service lines for approximately 16 hours. The text at the top of the graph describes the experimental testing conditions.

The time period labeled “No Treatment” shows accumulated lead concentrations in untreated DC tap water. During the no-treatment phase, contact between the water and the lead service line resulted in relatively high lead concentrations in tap water (100 to 250 parts per billion). On May 12, 2004, DCWASA began adding orthophosphate to the water in the loop 3 experiments. Thereafter, lead concentrations gradually decreased. Following approximately 34 weeks of treatment, lead concentrations are less than 15 parts per billion.

To date, DCWASA has tested orthophosphate treatment in a total of four recirculation loops. Similar trends were seen for all loops: lead leaching from lead service lines decreased when orthophosphate was added to the tap water. This information was key in the decision to start adding orthophosphate system-wide in August 2004.

Treatment update: Results in 2005 show that the orthophosphate treatment is working to reduce lead leaching. WASA reported that of the 100 homes tested by WASA from January – May 2005, 90 had lead levels at or below 15 ppb.

Figure 2 Laboratory Data: Updated January 2005
Laboratory Pipe Loop Study



Laboratory data from the stagnation loops should be interpreted with care. The amount of lead that leaches from a lead service line depends on many factors. The first is the nature of the service line itself. DCWASA uses excavated lead service lines from their system in all of their recirculation loops. The age of the service line, the way it was manufactured, and the quality of water it received can influence the amount of lead that leaches into drinking water. Another factor is that laboratory experiments are conducted under controlled conditions. In the distribution system and in individual homes, the quality of water can vary more than it does in the laboratory environment.

Continuing Research

DCWASA, the Washington Aqueduct, and EPA have agreed on a long-term research strategy to ensure that the best overall quality of water is provided to District residents. Below are examples of some of the research studies underway:

- ▶ DCWASA is continuing the pipe loop studies that have been underway. DCWASA is also testing innovative alternatives to service line replacement in the lab.
- ▶ The Washington Aqueduct is evaluating the effectiveness of orthophosphate and zinc orthophosphate treatment using an intricate flow-through pipe loop system. They are comparing the two chemicals to determine which chemical works best and to refine the treatment process. In related research, the Arlington Department of Environmental Services and EPA are jointly funding research to determine if adding zinc orthophosphate would cause waste water treatment problems.
- ▶ EPA is continuing to analyze lead service lines to assess how the lead scales inside the pipes are changing as a result of orthophosphate treatment.
- ▶ EPA is funding research to evaluate whether grounding currents and galvanic coupling of lead and copper service lines affect lead corrosion.
- ▶ The Aqueduct is conducting a pH management study of whether the current practice of using lime is the best way to maintain a consistent pH or whether other options could work more reliably.
- ▶ DCWASA is conducting extensive water quality monitoring to help manage the system and prioritize their unidirectional flushing program.

Continuing Consumer Advisory

Although recent lead monitoring in the District shows that the orthophosphate treatment is working to reduce lead leaching, it is important that District residents continue to follow the consumer advisory for flushing their taps and filtering before drinking the water.

Residents in homes known to have or suspected of having lead service lines should continue to:

ALWAYS run the water in your home for 10 minutes to flush the pipes before drinking or using it for cooking. *Showering or washing clothes counts as flushing*, but you should still run each faucet for 60 seconds before use.



Pregnant women, nursing mothers, and children under 6 years old should only drink filtered tap water. Flush the pipes for 10 minutes as noted above before using your home filter.

To conserve water and save time after flushing your taps each morning, fill up several clean containers of filtered water that you can store in the refrigerator and use during the day.

All residents should continue to:

- ▶ Flush water from the tap for 60 seconds before drinking or using it for cooking.
- ▶ Use only **COLD** water for drinking or cooking.
- ▶ Remove and clean the strainer/aerator/screen device on your faucet regularly.
- ▶ Remember that boiling water will not remove lead!



For more information, see EPA's Website at <http://www.epa.gov/dclead>

For more information:

U.S. EPA Safe Drinking Water Hotline	800/426-4791	http://www.epa.gov/dclead/
D.C. Water and Sewer Authority	202/787-2732	http://www.dcwasa.com/
D.C. Department of Health	202/671-0733	http://dchealth.dc.gov/
Washington Aqueduct.....	202/764-2753	http://washingtonaqueduct.nab.usace.army.mil/

A copy of the Aqueduct's desk top study of various corrosion control strategies is available on EPA's website at <http://www.epa.gov/dclead/CorrosionControl.pdf>.

See EPA's website at <http://www.epa.gov/dclead/chlorine.htm> for more information on the 2004 switch from chloramines to chlorine.

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